

NCL30088LED1GEVB

18 W High Power Factor LED Driver Evaluation Board User's Manual



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Eval Board User's Manual

Overview

This manual covers the specification, theory of operation, testing and construction of the NCL30088LED1GEVB demonstration board. The NCL30088 board demonstrates a 18 W high PF buck boost LED driver in a typical T8 outline.

Table 1. SPECIFICATIONS

| Parameter | Value | Comment |
|--|----------------|-----------|
| Input voltage (Class 2 Input, no ground) | 100 – 277 V ac | |
| Line Frequency | 50 Hz / 60 Hz | |
| Power Factor (100% Load) | 0.9 | Min |
| THD (Load > 30%) | 20% | Max |
| Output Voltage Range | 90 – 180 V dc | |
| Output Current | 100 mA dc | ±2% |
| Efficiency | 92% | Typical |
| Start Up Time | < 500 msec | Typical |
| EMI (conducted) | Class B | FCC/CISPR |

Key Features

As illustrated, the key features of this evaluation board include:

- Wide Mains
- Low THD across Line and Load
- High Power Factor across Wide Line and Load
- Integrated Auto Recovery Fault Protection (can be latched by Choice of Options)
 - ◆ Over Temperature on Board (a PCB mounted NTC)
 - ◆ Over Current
 - ◆ Output and Vcc Over Voltage



Figure 1. Evaluation Board Picture (Top View)

THEORY OF OPERATION

Power Stage

The power stage for the demo board is a non-isolated buck-boost based. The controller has a built in control algorithm that is specific to the flyback transfer function. Specifically:

$$\frac{V_{out}}{V_{in}} = \frac{Duty}{(1 - Duty)}$$

This is applicable to flyback, buck-boost, and SEPIC converters. The control is very similar to the control of the NCL30080-83 with the addition of a power factor correction control loop. The controller has a built in hardware algorithm that relates the output current to a reference on the primary side.

$$I_{out} = \frac{V_{ref} \times N_{ps}}{2 \times R_{sense}}$$

$$N_{ps} = \frac{N_{pri}}{N_{sec}}$$

Where N_{pri} = Primary Turns and N_{sec} = Secondary Turns
We can now find R_{sense} for a given output current.

$$R_{sense} = \frac{V_{ref} \times N_{ps}}{2 \times I_{out}}$$

Line Feedforward

The controller is designed to precisely regulate output current but variation input line voltage do have an impact. R3 sets the line feedforward and compensates for power stage delay times by reducing the current threshold as the line voltage increases. R3 is also used by the shorted pin detection. At start up the controller puts out a current to check for a shorted pin. If R3 is zero, the current sense resistor is too low a value and the controller will not start because it will detect a shorted pin. So R3 is required to make the controller operate properly. In practice, R3 should be greater than 250 Ω .

Voltage Sense

The voltage sense pin has several functions:

1. Basis for the reference of the PFC control loop
2. Line Range detection

The reference scaling is automatically controller inside the controller. While the voltage on V_s is not critical for the PFC loop control, it is important for the range detection. Generally the voltage on V_s should be 3.5 V peak at the highest input voltage of interest. The voltage on V_s determines which valley the power stage will operate in. At low line and maximum load, the power stage operates in the first valley (standard CrM operation). At the higher line range, the power stage moves to the second valley to lower the switching frequency while retaining the advantage of CrM soft switching.

Auxiliary Winding

The auxiliary winding has 3 functions:

1. CrM timing
2. Vcc Power
3. Output voltage sense

CrM Timing

In the off time, the voltage on the transformer/inductor forward biases D_{out} and D₉. When the current in the magnetic has reached zero, the voltage collapses to zero. This voltage collapse triggers a comparator on the ZCD pin to start a new switching cycle. The ZCD pin also counts rings on the auxiliary winding for higher order valley operation. A failure of the ZCD pin to reach a certain threshold also indicates a shorted output condition.

Vcc Power

The auxiliary winding forward biases D₉ to provide power for the controller. This arrangement is called a "bootstrap". Initially the C_{vcc} is charged through R₄ and R₅. When the voltage on C_{vcc} reaches the startup threshold, the controller starts switching and providing power to the output circuit and the C_{vcc}. C_{vcc} discharges as the controller draws current. As the output voltage rises, the auxiliary winding starts to provide all the power to the controller. Ideally, this happens before C_{vcc} discharges to the under voltage threshold where the controller stops operating to allow C_{vcc} to recharge once again. The size of the output capacitor will have a large effect on the rise of the output voltage. Since the LED driver is a current source, the rise of output voltage is directly dependent on the size of the output capacitor.

There are tradeoffs in the selection of C_{out} and C_{vcc}. A low output ripple will require a large C_{out} value. This requires that C_{vcc} be large enough to support Vcc power to the controller while C_{out} is charging up. A large value of C_{vcc} requires that R₄ and R₅ be lower in value to allow a fast enough startup time. Smaller values of R₄ and R₅ have higher static power dissipation which lowers efficiency of the driver.

Output Voltage Sense

The auxiliary winding voltage is proportional to the output voltage by the turns ratio of the output winding and the auxiliary winding. The controller has an overvoltage limit on the Vcc pin at about 26 V minimum. Above that threshold, the controller will stop operation and enter overvoltage fault mode such as when an open LED string occurs.

In cases where the output has a lot of ripple current and the LED has high dynamic resistance, the peak output voltage can be much higher than the average output voltage. The auxiliary winding will charge the C_{vcc} to the peak of the output voltage which may trigger the OVP sooner than expected so in this case the peak voltage of the LED string is critical.

SD Pin

The SD pin is a multi-function protection input.

1. Thermal Foldback Protection
2. Programmable OVP

Thermal Protection

There is an internal current source from the SD pin. Placing an NTC from the SD pin to ground will allow the designer to choose the level of current foldback protection from over temperature. Below 0.5 volts on SD, the controller stops. Series or parallel resistors on the NTC and shape the foldback curve. In the event that the pin is left open, there is a soft voltage clamp at 1.35 V (nominal). Output current is reduced when the voltage on the SD pin drops below 1 V.

Programmable OVP

While the SD pin has a current source for the OTP, it can be overcome raising the voltage on the SD pin. At about

2.5 V, the SD pin detects an OVP and shuts down the controller. Typically, a zener to Vcc is used for this. In this way, the designer can set the OVP to a lower value than the OVP threshold built into the Vcc pin.

Circuit Modifications

Output Current

The output current is set by the value of Rsense as shown above. It's possible to adjust the output current by changing R7. Since the magnetic is designed for 18 W, it is possible to increase the current while reducing the maximum LED forward voltage within limits. Changes of current of $\pm 10\%$ are within the existing EMI filter design and magnetic, changes of more than 10% may require further adjustments to the transformer or EMI filter.

NCL30088LED1GEVB

SCHEMATIC

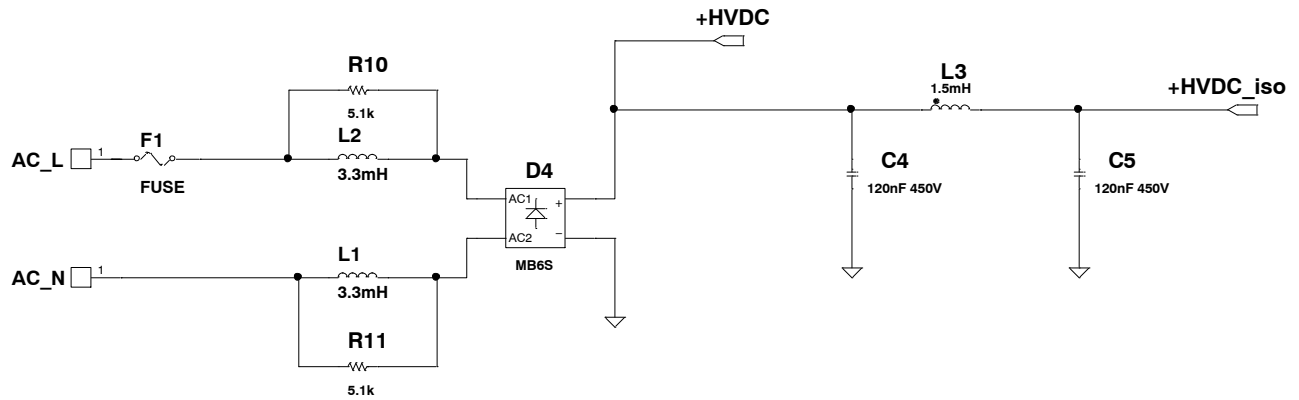


Figure 2. Input Circuit

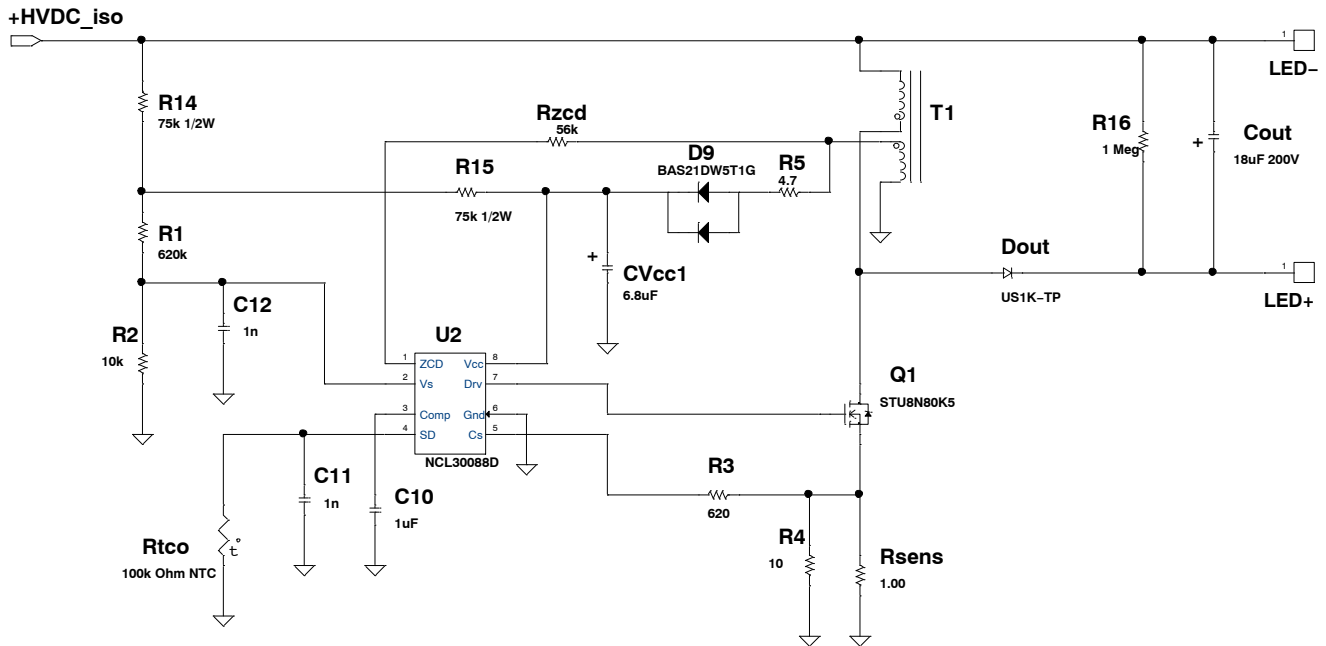


Figure 3. Main Schematic

NCL30088LED1GEVB

BILL OF MATERIAL

Table 2. BILL OF MATERIAL*

| Qty | Reference | Part | Manufacturer | Mfr_PN | PCB Footprint | Substitution Allowed |
|-----|-----------|---------------------|------------------|---------------------|-----------------------|----------------------|
| 1 | Cvcc1 | 6.8 μ F | TDK | C3216X7R1V685K160AC | 1206 | Yes |
| 1 | Cout | 18 μ F 200 V | Rubycon | 200LLE18MEFC10X12.5 | ALEL_10X12M5_VERT | Yes |
| 2 | C4, C5 | 120 nF 450 V | Panasonic | ECW-FD2W124KQ | CAP_BOX_12M6X4M6_LS10 | Yes |
| 1 | C10 | 1 μ F | Taiyo Yuden | TMK105BJ105MV-F | 402 | Yes |
| 2 | C11, C12 | 1 n | Kemet | C0402C102K3GACTU | 402 | Yes |
| 1 | Dout | US1K-TP | MCC | US1K-TP | SMA | Yes |
| 1 | D4 | MB6S | MCC | MB6S | MB6S | Yes |
| 1 | D9 | BAS21DW5T1G | ON Semiconductor | BAS21DW5T1G | SC-88A | No |
| 1 | F1 | FUSE | Littelfuse | 0263.500WRT1L | FUSE-HAIRPIN-L S250 | Yes |
| 2 | L1, L2 | 3.3 mH | Würth | 744772332 | RAD_IND_LS5 | Yes |
| 1 | L3 | 1.5 mH | Würth | 744772152 | RAD_IND_LS5 | Yes |
| 1 | Q1 | STU8N80KS | ST | STU8N80K5 | IPAK | Yes |
| 1 | Rtco | 100 k Ω NTC | Epcos | B57331V2104J60 | 603 | Yes |
| 1 | Rzcd | 56k | Yaego | RC1206FR-0756KL | 1206 | Yes |
| 1 | R1 | 620k | Yaego | RC1206FR-07620KL | 1206 | Yes |
| 1 | R2 | 10k | Yaego | RC0402FR-0710KL | 402 | Yes |
| 1 | R3 | 620 | Yaego | RC0402FR-07620RL | 402 | Yes |
| 1 | R5 | 4.7 | Yaego | RC1206FR-074R7L | 1206 | Yes |
| 2 | R10, R11 | 5.1k | Yaego | RC1206FR-075K1L | 1206 | Yes |
| 2 | R14, R15 | 75k $\frac{1}{2}$ W | Stackpole | RNCP1206FTD75K0 | 1206 | Yes |
| 1 | R16 | 1 Meg | Yaego | RC1206JR-071ML | 1206 | Yes |
| 1 | T1 | XFRM_LINEAR | Würth | 750314731 | RM6_4P | Yes |
| 6" | W1 | Wire, Red, 24AWG | McMaster Carr | 7587K922 | UL1569 | Yes |
| 6" | W2 | Wire, Blk, 24AWG | McMaster Carr | 7587K921 | UL1569 | Yes |
| 12" | W3, W4 | Wire, Wht, 24AWG | McMaster Carr | 7587K924 | UL1569 | Yes |

*All Components to comply with RoHS 2002/95/EC

Construction Options

| NCL30088B Revision 00 | | | | | | |
|-----------------------|-------|-----------|------------------|------------------|------|-----|
| 1 | U2 | NCL30088B | ON Semiconductor | NCL30088B | SO8 | No |
| 1 | Rsens | 1.13 | Yaego | RC1206FR-071R13L | 1206 | Yes |
| 1 | R4 | No Stuff | Yaego | RC0805JR-0710RL | 805 | Yes |
| NCL30088D Revision 01 | | | | | | |
| 1 | U2 | NCL30088D | ON Semiconductor | NCL30088D | SO8 | No |
| 1 | Rsens | 1 | Yaego | RC1206FR-071RL | 1206 | Yes |
| 1 | R4 | 10 | Yaego | RC0805JR-0710RL | 805 | Yes |

NCL30088LED1GEVB

GERBER VIEWS

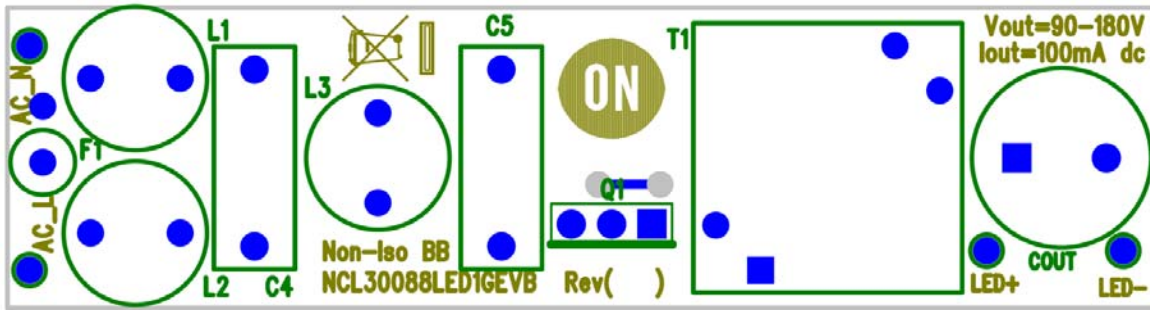


Figure 4. Top Side PCB

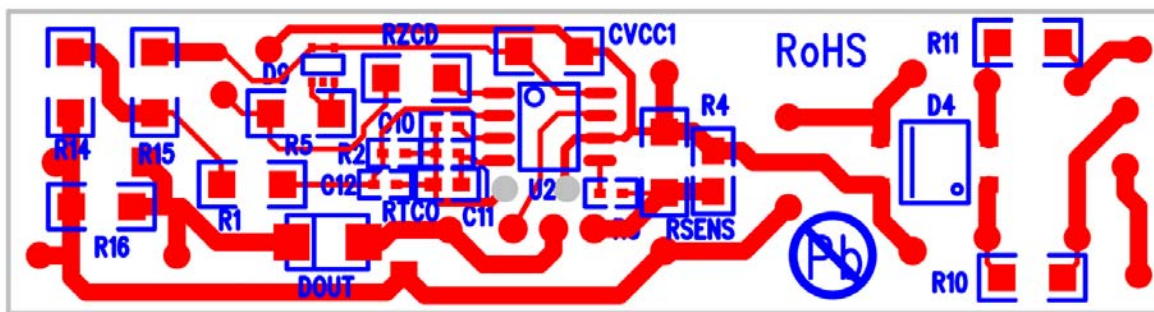
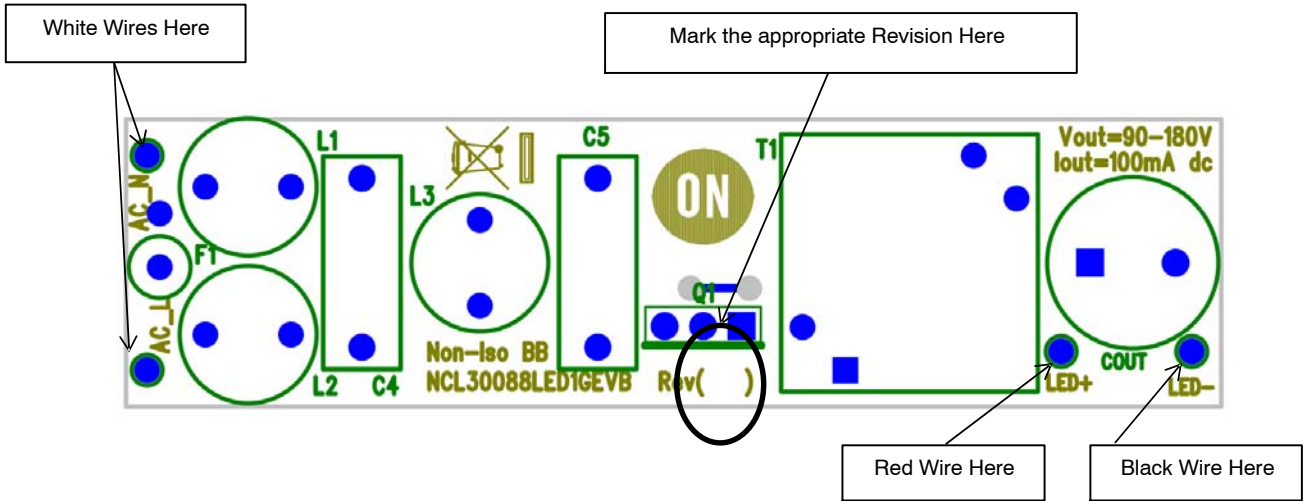


Figure 5. Bottom Side PCB



Figure 6. PCB Outline

NCL30088LED1GEVB



1. Strip and tin lead wires to $6'' \pm 0.5''$ 4 Places.



Figure 7. Assembly Notes

NCL30088LED1GEVB

CIRCUIT BOARD FABRICATION NOTES

1. Fabricate per IPC-6011 and IPC6012. Inspect to IPA-A-600 Class 2 or updated standard.
2. Printed Circuit Board is defined by files listed in fileset.
3. Modification to copper within the PCB outline is not allowed without permission, except where noted otherwise. The manufacturer may make adjustments to compensate for manufacturing process, but the final PCB is required to reflect the associated gerber file design ± 0.001 in. for etched features within the PCB outline.
4. Material in accordance with IPC-4101/21, FR4, Tg 125°C min.
5. Layer to layer registration shall not exceed ± 0.004 in.
6. External finished copper conductor thickness shall be 0.0026 in. min. (ie 2oz)
7. Copper plating thickness for through holes shall be 0.0013 in. min. (ie 1oz)
8. All holes sizes are finished hole size.
9. Finished PCB thickness 0.031 in.
10. All un-dimensioned holes to be drilled using the NC drill data.
11. Size tolerance of plated holes: ± 0.003 in. : non-plated holes ± 0.002 in.
12. All holes shall be ± 0.003 in. of their true position U.D.S.
13. Construction to be SMOBC, using liquid photo image (LPI) solder mask in accordance with IPC-SM-B40C, Type B, Class 2, and be green in color.
14. Solder mask mis-registration ± 0.004 in. max.
15. Silkscreen shall be permanent non-conductive white ink.
16. The fabrication process shall be UL approved and the PCB shall have a flammability rating of UL94V0 to be marked on the solder side in silkscreen with date, manufactures approved logo, and type designation.
17. Warp and twist of the PCB shall not exceed 0.0075 in. per in.
18. 100% electrical verification required.
19. Surface finish: electroless nickel immersion gold (ENIG)
20. RoHS 2002/95/EC compliance required.

NCL3008LED1GEVB

BUCK BOOST INDUCTOR SPECIFICATION

| | | | |
|-------------------|------|---------------|--|
| CUSTOMER TERMINAL | RoHS | LEAD(Pb)-FREE | |
| Sn96%, Ag4% | Yes | Yes | |

TERM. NO.'s FOR REF. ONLY

LOT CODE & DATE CODE

NOTCH IN UPPER FLANGE LOCATES TERM. #1 SIDE

Part must insert fully to surface A in recommended grid

RECOMMENDED P.C. PATTERN, COMPONENT SIDE

ELECTRICAL SPECIFICATIONS @ 25 °C unless otherwise noted:

D.C. RESISTANCE (@20 °C): 6-2, 1.35 Ohms ±10%.
3-5, 0.425 Ohms ±10%.

DIELECTRIC RATING: 500VAC, 1 minute tested by applying 625VAC for 1 second between pins 6-3.

INDUCTANCE: 1.25mH ±8%, 100kHz, 100mVAC, 0mADC, 6-2, Ls.

SATURATION CURRENT: >1.0ADC saturating current that causes 20% rolloff from initial inductance.

LEAKAGE INDUCTANCE: 85µH typ., 120µH max., 100kHz, 100mVAC, 6-2(tie 3+5), Ls.

URNS RATIO: (6-2):(3-5), (8):(1.00), ±2%.

OPERATING TEMPERATURE RANGE: -40 °C to +125 °C including temp rise.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

| | | | |
|---|---|------------------------------------|-------------------|
| Würth Electronics Midcom Inc. Watertown, SD USA Toll Free: 800-643-2661 Fax: 605-886-4486 | Unless otherwise specified, tolerances are as follows: Angles: ±1° Fractions: ±1/64 Decimals: ±.005(.127mm) Footprint: ±.001(.03mm) | more than you expect | |
| | Drawing Title Inductor | Drawing Number 750314731 | Rev. 00 |
| This drawing is dual dimensioned. Dimensions in brackets are in millimeters | Revisions: See Sheet 1 | Scale ---- | Spec Sheet 1 of 1 |
| Engineer: EJK | | 04/10/2014 | |

NCL30088LED1GEVB

ECA PICTURES

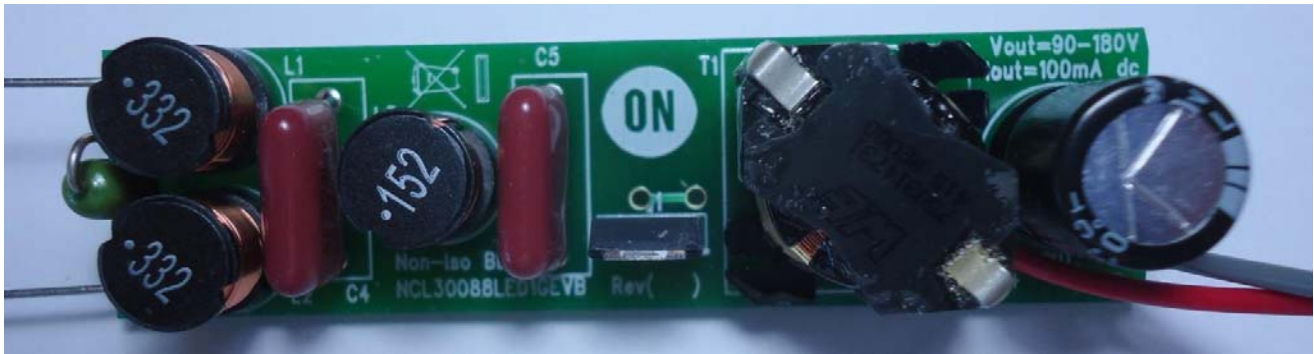


Figure 8. Top View

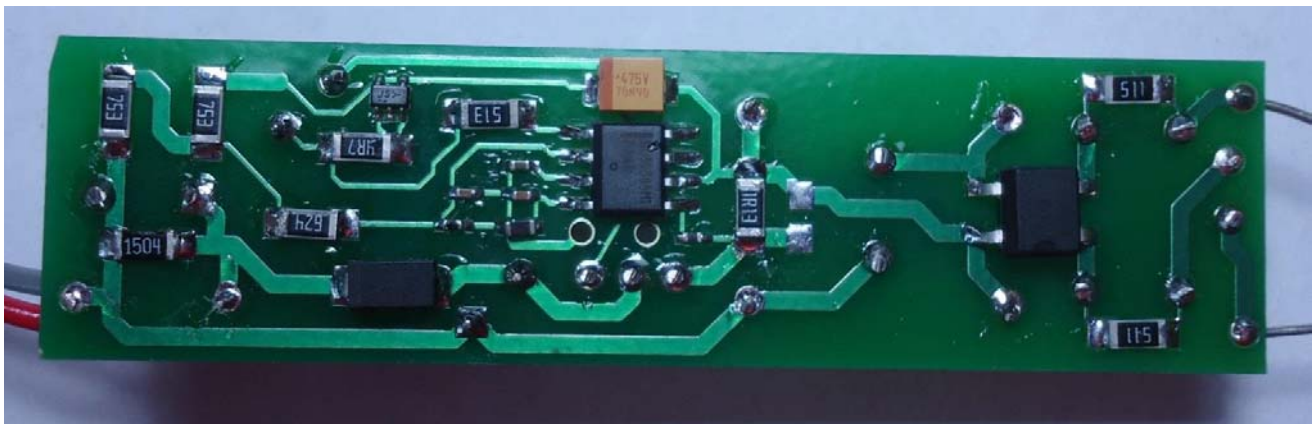


Figure 9. Bottom View

TEST PROCEDURE

Equipment Needed

- AC Source – 90 to 305 V ac 50/60 Hz Minimum 500 W capability
- AC Wattmeter – 300 W Minimum, True RMS Input Voltage, Current, Power Factor, and THD 0.2% accuracy or better
- DC Voltmeter – 300 V dc minimum 0.1% accuracy or better
- DC Ammeter – 1 A dc minimum 0.1% accuracy or better

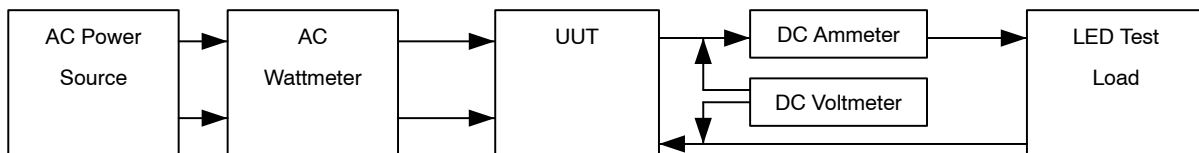
- LED Load – 10 V – 30 V @ 1 A

Test Connections

1. Connect the LED Load to the red (+) and black (-) leads through the ammeter shown in Figure 10.

CAUTION: Observe the correct polarity or the load may be damaged.

2. Connect the AC power to the input of the AC wattmeter shown in Figure 10. Connect the white leads to the output of the AC wattmeter
3. Connect the DC voltmeter as shown in Figure 10.



NOTE: Unless otherwise specified, all voltage measurements are taken at the terminals of the UUT.

Figure 10. Test Set Up

NCL30088LED1GEVB

Functional Test Procedure

1. Set the LED Load for 26 V output.
2. Set the input power to 120 V 60 Hz.

CAUTION: Do not touch the ECA once it is energized because there are hazardous voltages present.

LINE AND LOAD REGULATION

Table 3. 120 V / MAX LOAD

| | Output Current 100 mA ± 3 mA | Output Power | Power Factor | THD < 20% |
|-------|---------------------------------|--------------|--------------|-----------|
| 90 V | | | | |
| 135 V | | | | |
| 180 V | | | | |

Table 4. 230 V / MAX LOAD

| | Output Current 100 mA ± 3 mA | Output Power | Power Factor | THD < 20% |
|-------|---------------------------------|--------------|--------------|-----------|
| 90 V | | | | |
| 135 V | | | | |
| 180 V | | | | |

$$\text{Efficiency} = \frac{V_{\text{out}} \times I_{\text{out}}}{P_{\text{in}}} \times 100\%$$

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TEST DATA

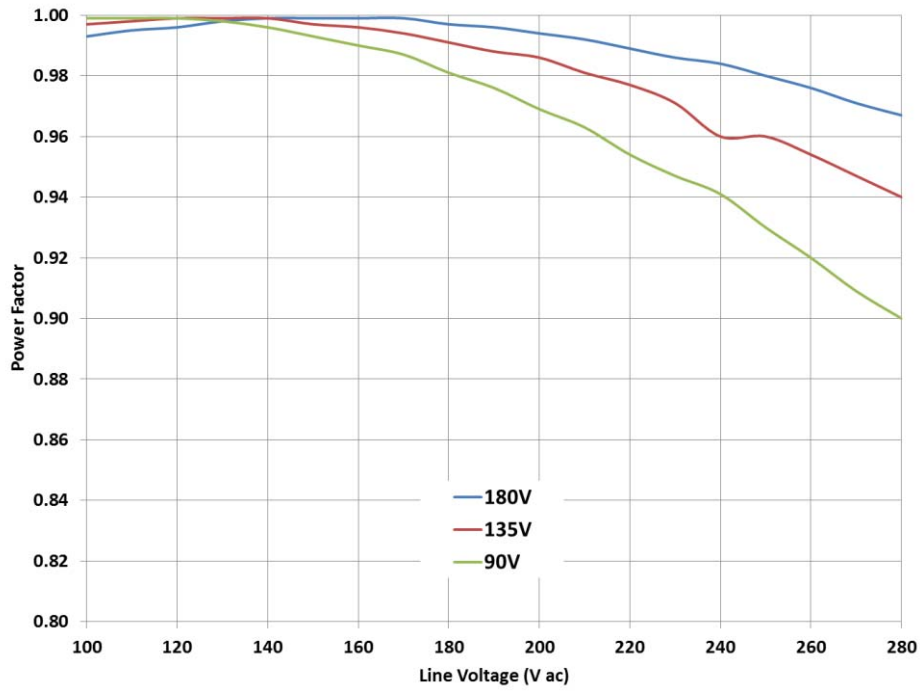


Figure 11. Power Factor over Line and Load

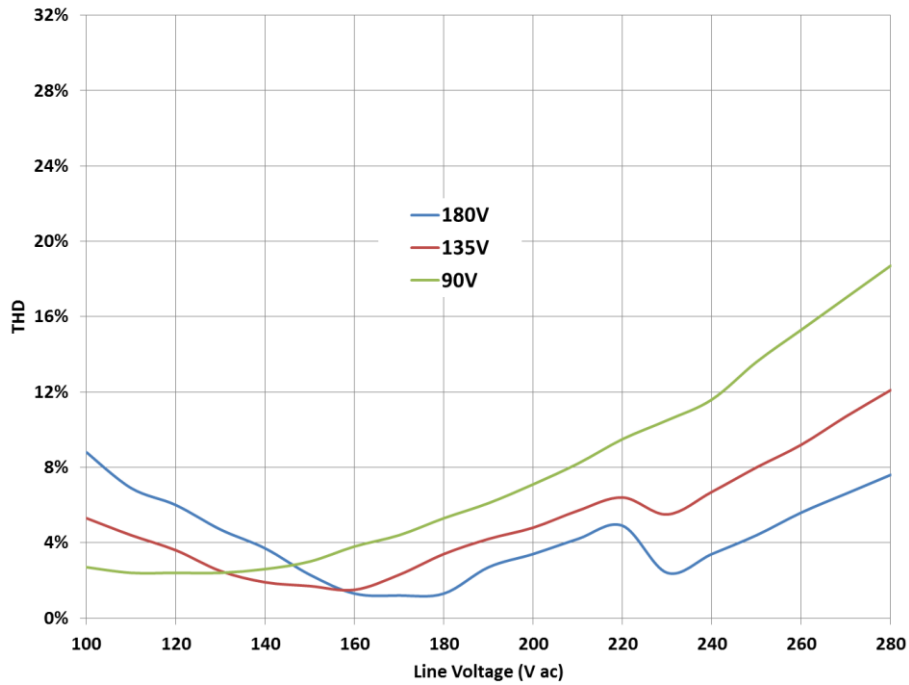


Figure 12. THD over Line and Load

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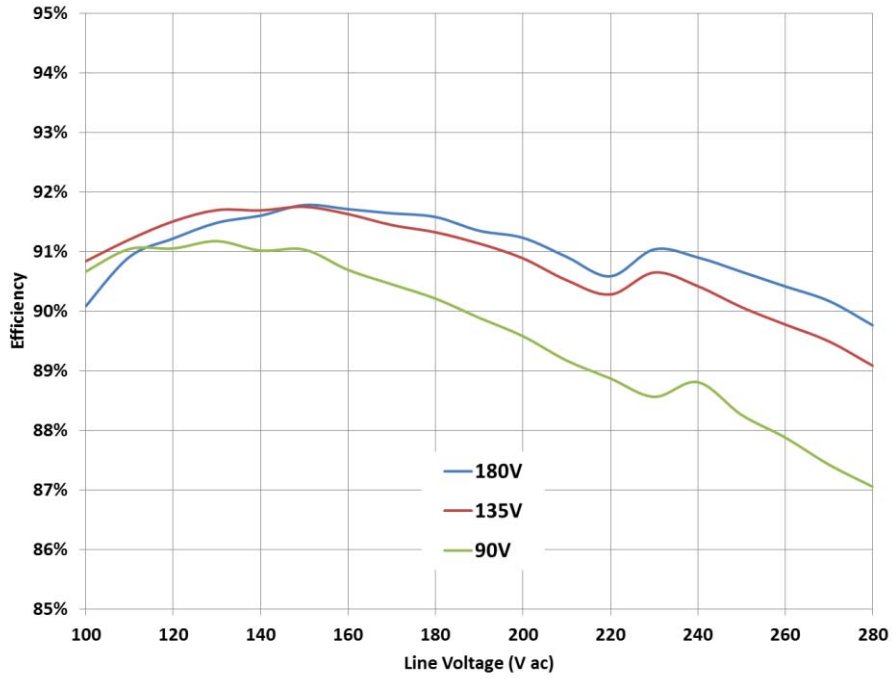


Figure 13. Efficiency over Line and Load

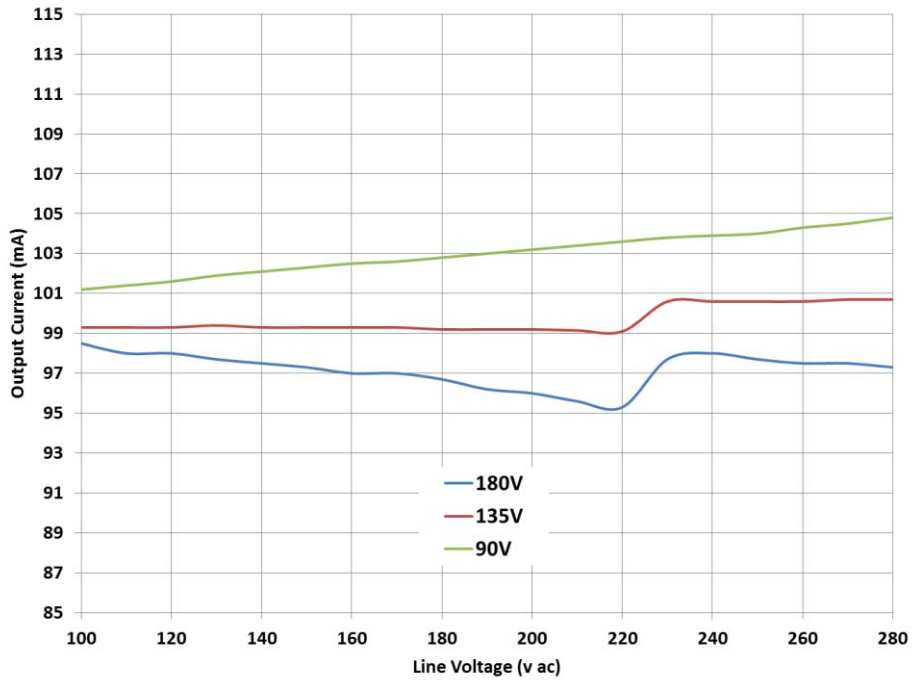


Figure 14. Regulation over Line

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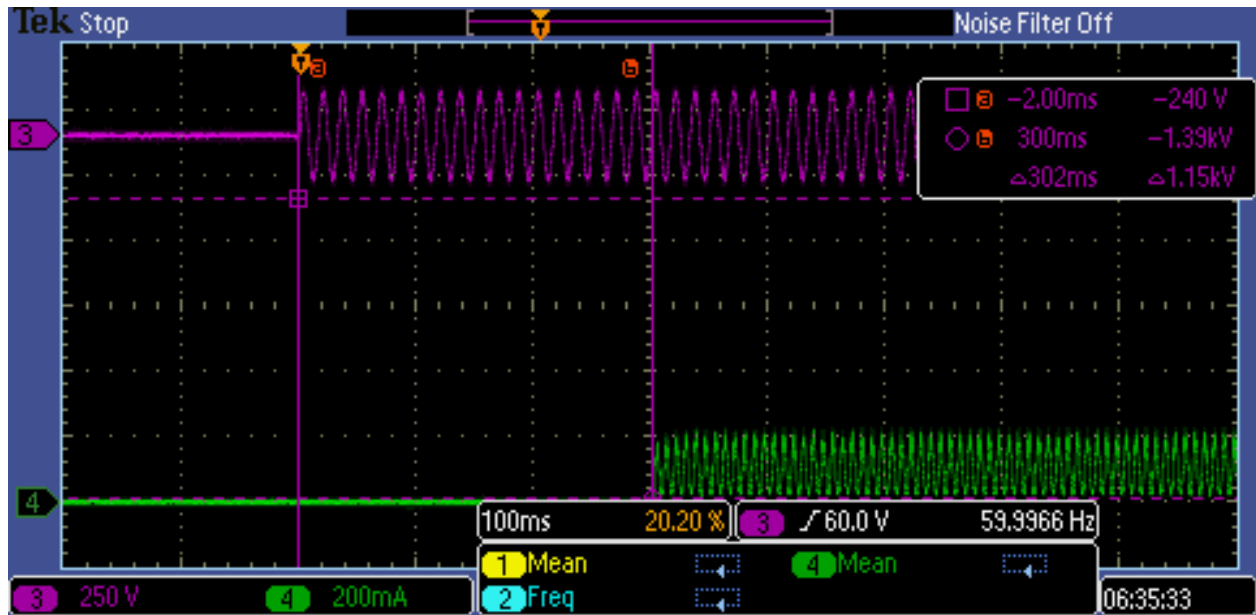


Figure 15. Start Up with AC Applied 120 V Maximum Load

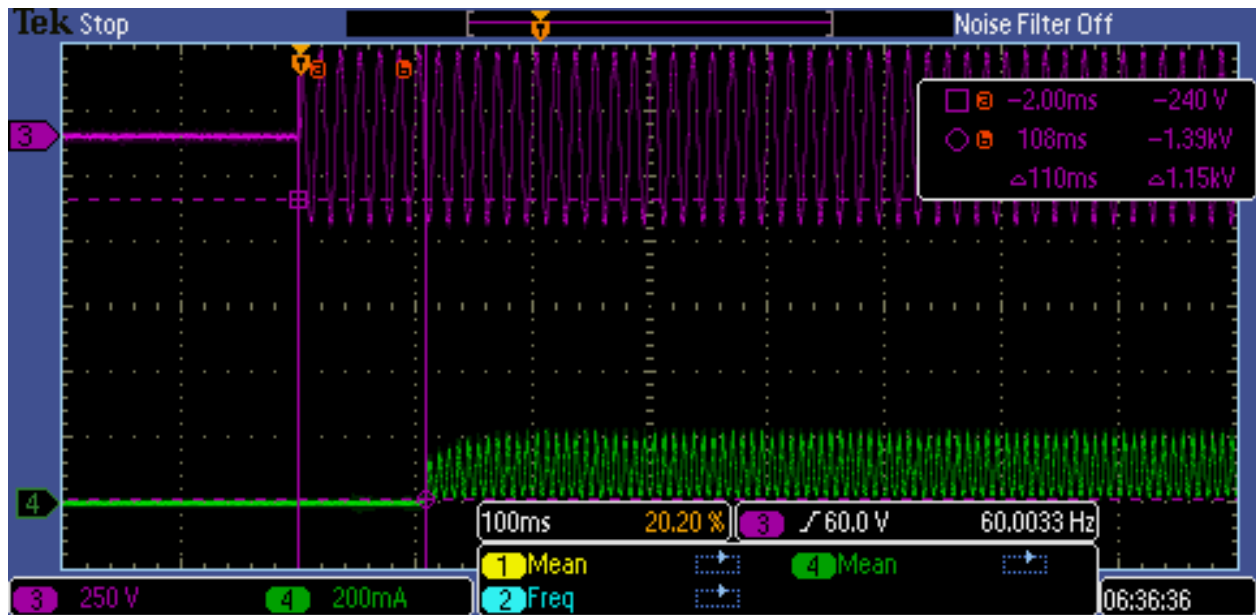


Figure 16. Start Up with AC Applied 230 V Maximum Load

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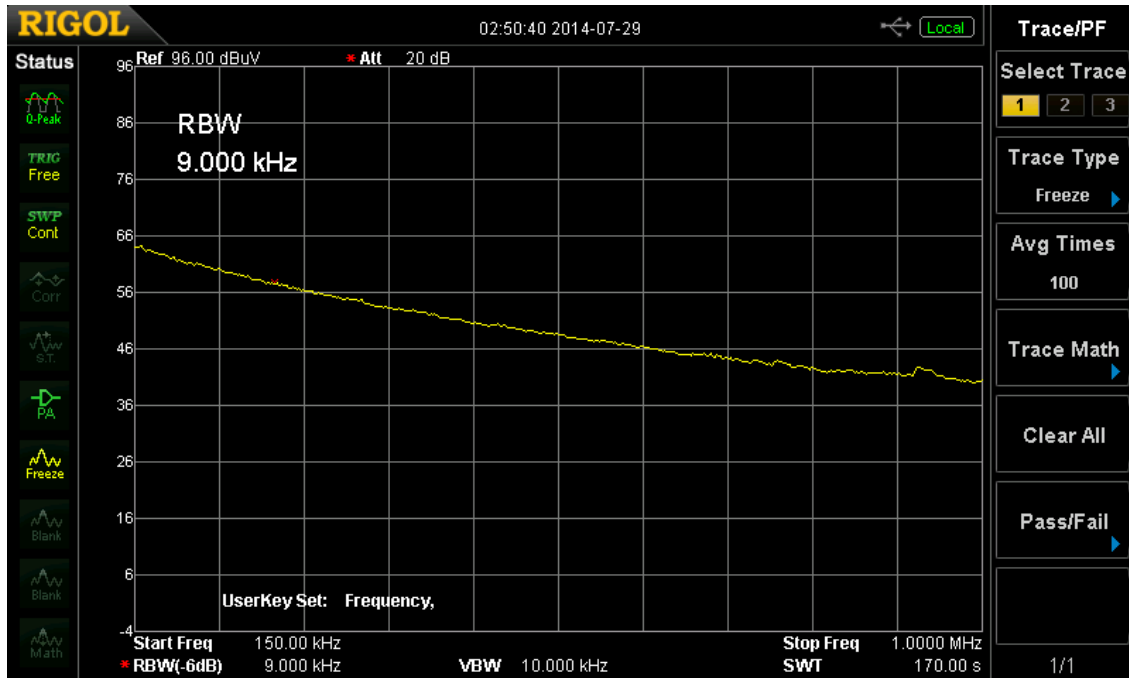


Figure 17. Conducted EMI Pre-compliance QP Data 150 kHz – 1 MHz

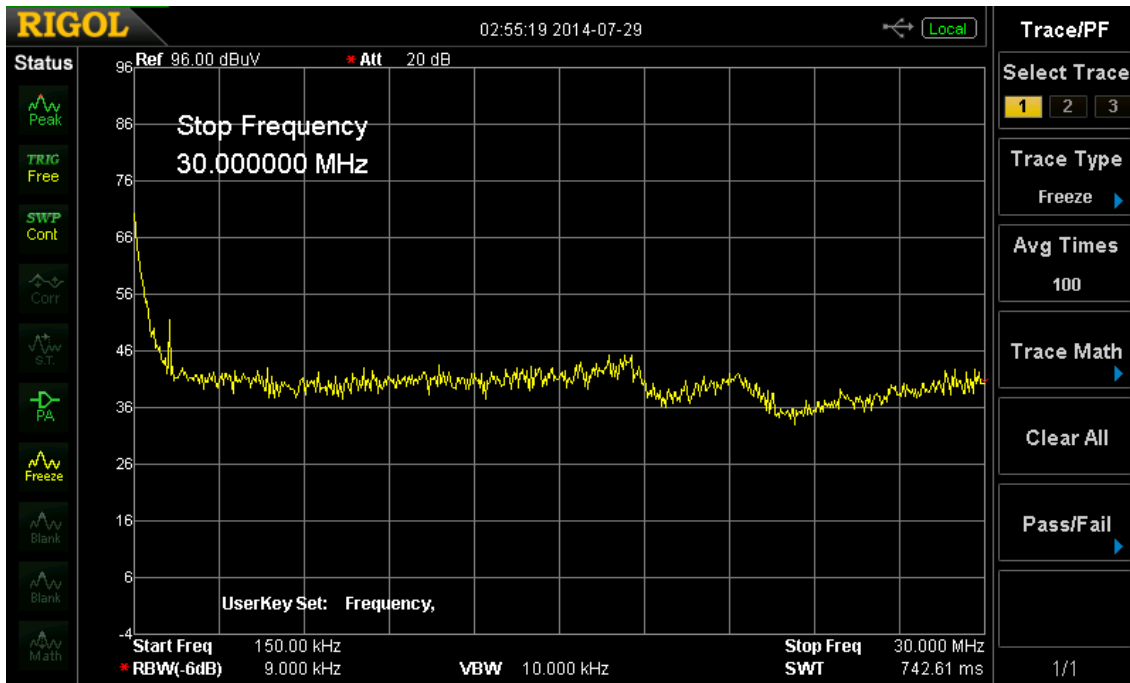



Figure 18. Conducted EMI Pre-compliance Peak Data 150 kHz – 30 MHz

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